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Rise of Fluid Computing: A Collective Effort Of Mist, Fog and Cloud

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Abstract — Every device including the state-of-the-art technologies heavily rely on computers to store and process information. Such a feat was achieved with the evolution of cloud computing. It gave consumers the ability of remote execution as well as reducing the complexity of managing the resources. The introduction of Edge computing consisting of Fog and Mist addressed the real-time application-oriented problems and provided with quick onsite solutions. Both Cloud and Edge are quite different and address different problem statements. This paper merges both the computing architectures to form a hybrid computing architecture named Fluid Computing. Fluid Computing is a combination of Mist, Fog and Cloud computing. The Fluid takes advantage of Edge by collaborating it with Cloud where the need for real-time solution provider was much needed. The paper discusses the interoperability between the three computing paradigms and solves their individual flaws by a collective effort, eventually giving rise to fluid computing. This is done by considering a use-case scenario, comparing and contrasting various feature aspects and visualizing the implementation of the technology behind it. The paper also paves the way for implementing machine learning, artificial intelligence in existing models to build smarter devices.

Keywords*—Fluid Computing, IoT, Mist Computing, Fog Computing, Cloud Computing, Edge Computing, Gateway, Thinnect*

I. INTRODUCTION

The last decade marked the evolution of cloud computing as it emerged to be the most famous on-demand resource providing interface. Some features of cloud computing that took it to such heights include – choice, scalability, speed, integration, audit and compliance, business continuity planning and most effectively being cost efficient. Due to this most of the companies started investing and purchasing various cloud services. This led to rapid development in the technology which in turn offered various cloud services to the users. The need of involving cloud in every aspect of technology became a necessity. Especially in IoT, the data produced by every device needs to be stored in a centralized cloud platform. But as more and more devices get connected to the network, the management of resources becomes increasingly complex. Not being able to attend to real-time system analysis is a major disadvantage on the part of cloud computing. As a remedy to the problem, new types of computing emerged - Fog Computing, Mist Computing. They are a part of Edge Computing, where the computational power is passed on to the very edge of the network, that is to the gateways, sensors and actuators. The effective and collective work of edge computing alongside cloud computing gave rise to fluid computing, where data transfers like a fluid from one computing architecture to another.

The paper is divided into seven sections. Section I briefly introduces to the concept of different computing paradigms, Section II contains the problem statement highlighting the need of fluid over existing computing architectures, Section III provides an architecture of fluid computing integrating the three computing models, Section IV explains the working of fluid computing with a dataflow diagram, Section V contains a case study where fluid computing could be put into use, Section VI compares and contrasts the different computing architectures and Section VII concludes the research work with future directions.

II. PROBLEM STATEMENT

In real-time system analysis or in conditions where decisions are to be made in impromptus situations, relaying the environment conditions to the cloud and waiting for the actions might not be decisive. Consider an event where a thief enters a shop which has surveillance cameras. The cameras would transmit the live footages to the cloud, where the raw footages would be analyzed and the confirmation of identification of the person as thief would be conveyed to the store manager via some cloud services. By the time this happens the thief might have caused some damage to the store. In cases of network failures where communication with the cloud is limited, the application of real-time systems fails. Such problems could be solved with **Edge computing**

[1][2]. Having the computational power in the edge nodes could provide the system the real-time computation that it needs. The data could further be translated to cloud for analysis and storage. This cooperative functioning of the computing architectures not only builds efficiency but also makes the system highly sustainable.

A. Cloud Computing

Cloud computing refers to online based computer services that are made available to the users provided by some remote servers. The main objective is to reduce the workload and cost by not installing the software on the local machine rather than installing them on remote servers that everyone can use based on their need. Three different kinds of service models [3] that is provided in cloud are – Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). Huge amount of data can be stored in cloud and be processed according to the need.

B. Fog Computing

Fog computing is a paradigm of putting the computing ability in between the cloud server and the device sensors [4]. This capability is usually put into a device that acts as a gateway, connecting all of the sensors and managing connectivity with the cloud. The gateway device tends to have decent computing power and data storage, so it can handle data received from multiple sensors.

Fog computing plays a vital role in systems requiring critical latency and quick solutions. Automated driving is an example where fog computing thrives [5]. Along with delivering impromptu solution it also sends data required for further analysis to the cloud [6]. The system not only provides quick solutions but also reduces the data bandwidth that would have been otherwise used to relay data to cloud.

But the problem that fog computing faces is its sole dependence on the gateway device. The solution to this problem is making the computation go further to the edge of the system, to the sensors and actuators. Such computing paradigm is known as Mist Computing.

C. Mist Computing

Mist computing puts the computing power in the edge of the system in forms of microchips and micro controllers. Hence the computation power is quite limited.

The use of mist computing is often questioned, so as the use of sensors is only to record the environment, why put the computing power? The sensors not only record the environment but also relay the same to the server. Sometimes relaying such information consumes more power than computing the result on the go. So, by having computing power on the sensor, the data can be processed, preconditioned, and optimized first before being stored. The resulting data will be much smaller, consuming less power in the transfer. The mist computing architecture could extend the capabilities of fog and reduce the processing needed by providing a faster result to certain input conditions. For complex problems, it could relay the data to fog architecture for further analysis and processing [7].

D. Need For Integrated Computing Model (Fluid Computing)

The cloud and fog have awareness of the user needs and the global situation whereas the mist has awareness to the physical environment and the local situation, so together the responsibility is to execute an IOT application [8][9]. In order to achieve this the global situation must be communicated to the edge devices and the edge devices must be able to understand how they need to behave in certain situations. The advantages with mist computing are - it has functionalities, timings which are dynamic and adjustable, there are high level application specific rules, new applications can be assembled from existing devices at runtime.

For example, when we install a movement sensor the information it provides as a service of movement detection, can be used by any device which is connected to that network. It can be used by a light sensor to turn the light on when there is movement or it can be used by an alarm system to provide an alarm if there should not be anyone in that area at that time.
The mist and fog architectures interact with the physical environment while cloud interacts with the data sent to it. The system thus formed is reliable and secured.

III. SYSTEM ARCHITECTURE

In Fig.1, the architecture of fluid computing paradigm is visualized

- The ***cloud computing*** operates on the top of the network. To compute any given operation the sensors directly send data through the gateway to the cloud repositories.
- The server processes, analyses and stores the data along with sending the output to the actuators through the gateway.
- If there is a condition in which instantaneous action is required and mist (present at the edge of the network) is unable to process the operation then the data is sent to fog computing which is present beneath the cloud computing near the ***gateway***.
- The ***fog computing*** has less computational power than the cloud but it produces real-time application-oriented output.
- The fog computing performs computation in less time than cloud and give back result to the ***actuators***.

- At last if there is any situation where faster and light computation is required then ***mist computing*** comes in handy. Without sending anything to fog or cloud it performs the computing with the help of ***micro-controllers*** present and it sends back to the actuators.

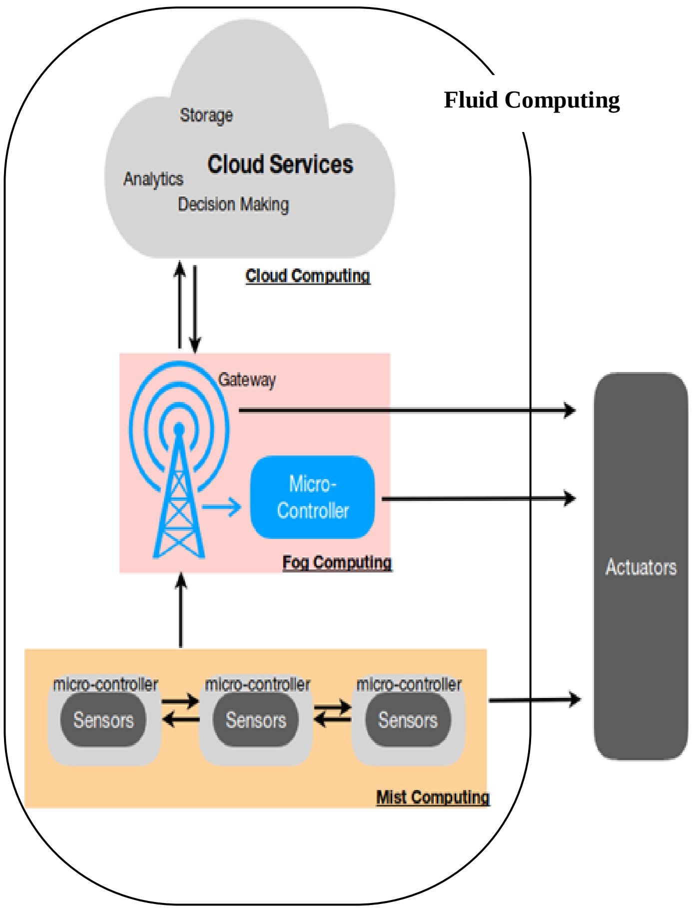

Fig.1. System Architecture

IV. ARCHITECTURE WORK FLOW DIAGRAM

The workflow diagram (Fig.2) explains the periodic movement of data right from the sensors to the actuators via fog and cloud architectures.

- The ***sensors*** first collect data, and then data is pre-processed, formatted, and other basic operations are carried out in the ***micro-controller*** present alongside the sensor. Both the sensory units and the micro-controllers present near it form mist computing.

- Then the mist computing checks if the required computation demand can be carried out. If it is possible then, the **micro-controller** present in the ***mist computing*** executes the operation. After the execution, the result is transferred to the ***actuators*** to act upon. The actuators then send a signal back to the micro-controller present in the mist computing architecture saying the task was carried out [10].

- If not, that is the mist computing cannot handle the request, then the data is passed to the micro-controller present in the gateway that form the fog ***architecture***. Here the computation is carried is carried out and the result is passed to the actuators to act upon and the actuators send the signal back to the fog when the work is completed [11].

- If solution is not required then data is transferred directly to the ***cloud*** for storage and analysis.

- If instantaneous output is not required then the data that is preprocessed by mist is transferred to the cloud from *gateway*. Various operations are performed on the cloud as per the request and the output from cloud is then transferred to the *actuators* via the *gateway*. The operation information or the logs are kept in the cloud for further query and analysis.

- The mist computing preprocessed the data and performs some small computations. The fog majorly performs all the tasks that require instantaneous application-based solutions. In case there is no need for instantaneous solution, the cloud takes over. All the operations that take place in the architecture are notified to the cloud. The cloud stores all the information and analyses the whole system [12].

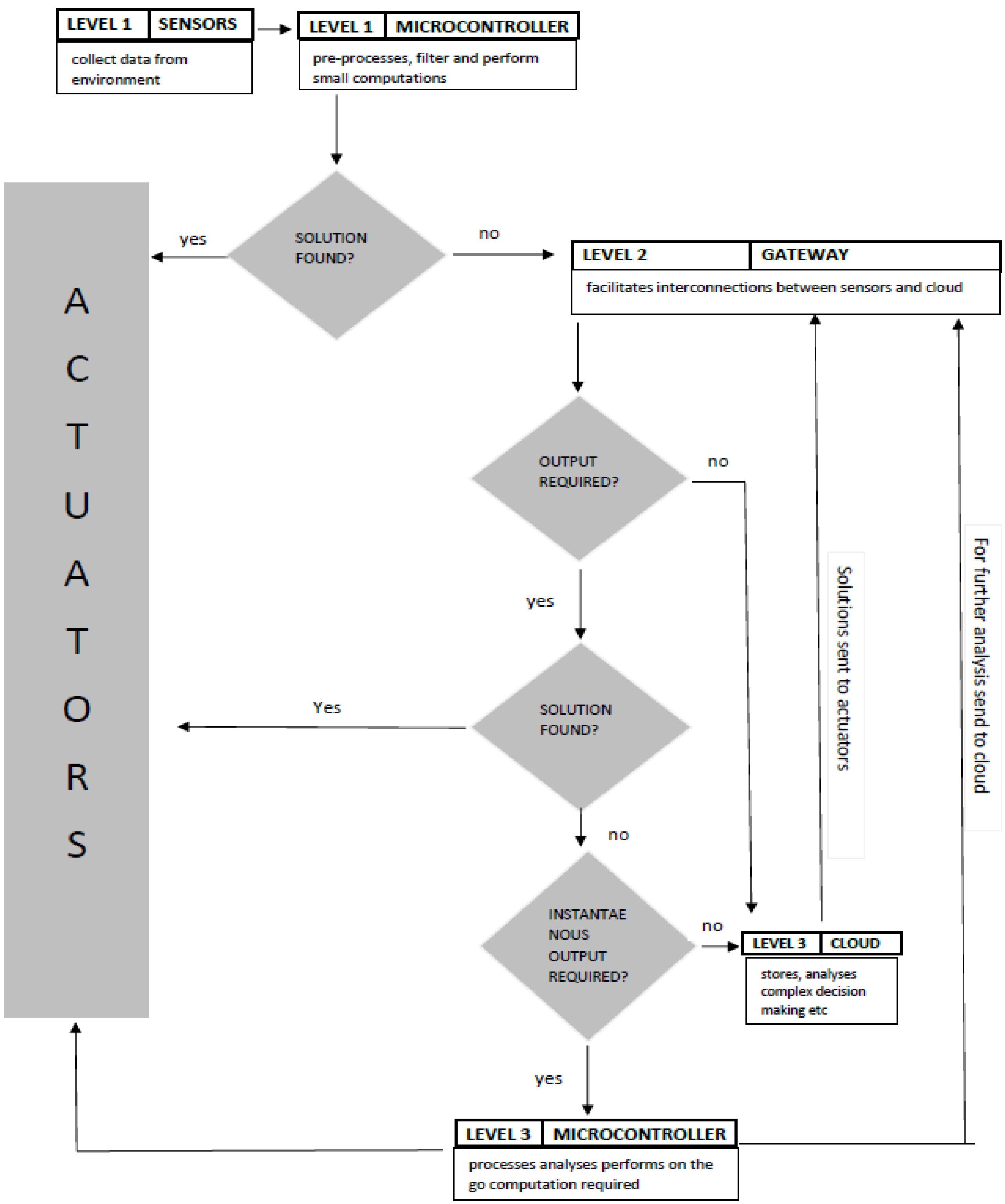

Fig.2. Architecture Workflow Diagram

V. APPLICATION AND CASE STUDY

A. Applications

The real-life application of mist computing was successfully implemented by Thinnect under the CEO Jugo Preden. It has successfully implemented a mist computing stack from the physical contrains by a robust rule-based application logic framework. The memory requirement of the entire stack is about 100 KBs. It has been deployed and tested by DEFENDEC for 6 years in a security application and recently in a smart city application in many countries by an organisation named CITYNTEL.

B. Case Study

Lets' consider a case where Cloud, Fog and Mist Computing work collectively for the effective functioning of a system, Fig.3.

- In case of a self-automated car, the sensors continuously record the environmental data through ***multiple sensors*** and processes them.
- ***Cloud Computing*** solves most of the issues where the system has no time limitation to process data like parking, traffic information, etc. In such cases the system sends data to the cloud and waits for the output.
- But in conditions like sudden appearance of an obstacle in front of car, sending the data to the cloud and waiting for the results would be fatal.
- So, here all ***Cloud, Fog and Mist*** act as a closed system to carry out the situation. When the sensors in the car encounter an obstacle, it sends data about the size, its distance from the car, speed of the car etc. to the fog system
- The *Fog system* then analyses this data and sends the report about braking, handling, etc., to the actuators to act upon. The Fog then filters the relevant data to be sent to cloud for further analysis.
- In this whole scenario the data flows from one architecture to another without any difficulties. This flow of data is fluidic in nature combining the Mist, Fog and Cloud Computing models.

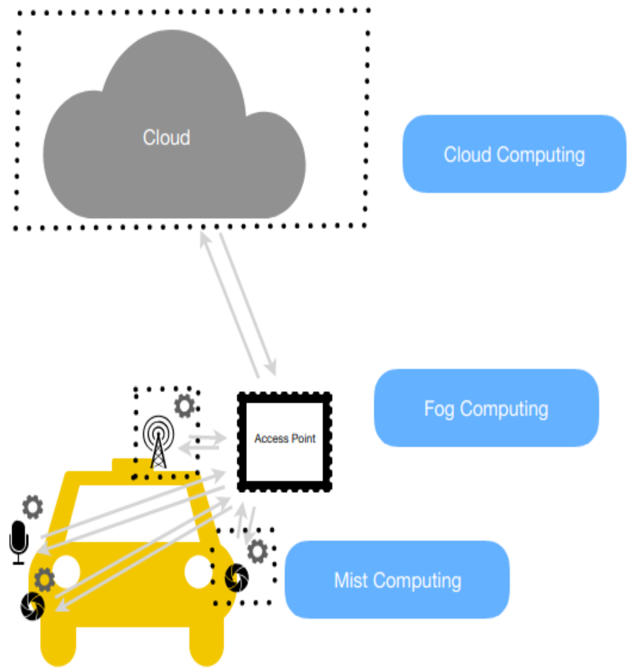

Fig.3. Mist Integrated model of Cloud and Fog Computing

VI. COMPARATIVE STUDY

The comparative study of the different computing in the proposed architecture is elaborately discussed and given in Table.1.

A. Computing Capability

Mist computing has the lowest computing capabilities amongst Fog and Cloud.

- The sensors directly perform the computations in mist so, there isn't much power or resources to compute higher and complex problems.
- Fog has better computing capabilities as compared to Mist. It is present in the gateways or access points and performs quick and complex operations that are required. It even replaces the cloud in terms of computing where the connectivity is limited.

B. Latency

The latency is lowest in Mist as the computational power is present in the physical site.

- The first response to any given situation is given by the mist computing.
- The fog comes next with next best latency.

- The cloud has the highest latency among the rest as the data has to be transferred to the cloud to get computed and register a response.
- The fluid computing works with the mist level to provide with first immediate response while sending the data to the cloud in the background waiting for the appropriate response. So, the system need not wait for response in case it is required

C. Scalability

The cloud is more flexible when it comes to scalability.

- The resources in cloud can be easily scaled up or scaled down based on the user needs.
- It is difficult for Mist, Fog to scale up and scale down as the resources have to be distributed and the connections have to be reconfigured.
- The fluid makes it easier as it operates along with edge and cloud. When storage is needed it just upgrades it in the cloud and when more local processing is needed, then it implements that at the edge level

D. Architecture

When it comes to the architecture,

- The fog and mist have a decentralized architecture where the computing power is distributed across the nodes. In case of failure of one node, the system maintains the integrity without jeopardizing or compromising it.
- The cloud has a centralized architecture where there is a chance of single point failure.
- The fluid has a hybrid architecture where at the lower level it is decentralized and at the upper level it is centralized.

E. Security

Fluid offers highest security amongst the others.

- The edge computing is susceptible to physical data modification, but is immune to most of the cyber threats.
- The cloud on the other hand is immune to physical data changes and is susceptible to cyber-attacks.

Table 1. Comparative Study of different computing in the architecture.

	MIST	FOG	CLOUD	FLUID
COMPUTING CAPABILITY	Low	Moderate	Very High	Dynamic
LATENCY	Very Low	Moderate	High	low
SCALABILITY	Very Difficult	Difficult	Very Easy	Easy, But Complex
ARCHITECTURE	Decentralised	Decentralised	Centralised	Hybrid
SECURITY	Very Low	Moderate	High	Very High
POWER CONSUMPTION	Low	Moderate	High	Dynamic, depends on Computation
REAL TIME ANALYSIS	Possible	Possible	Not Possible	Possible
COST	High, gradually decrease with use	Moderate	High	Very High

- Combining the edge and cloud and picking their pros, it can be concluded that they solve their individual demerits with each other's advantages.

F. Power Consumption

Computational power is directly related to the power consumption.

- As mist has the lowest computational power it has lowest power consumption.
- The fog has intermediate power consumption.
- The cloud has more power consumption as it is required to process large amount of data with high complexity.
- The fluid's computational power is dynamic so is its power consumption. It is based on the task, and its complexity. The consumption can be as low as mist or as high as cloud.

G. Real Time Analysis

The real-time system analysis is a major advantage on the part of edge computing.

- The Edge computing comprising Mist and Fog can provide quick instantaneous responses.
- The cloud takes quite a lot of time in proving outputs through the actuators to act upon.

The fluid takes rapid action as it has edge computing and cloud computing as a conjugation.

H. Cost

Fluid computing is the costliest as it combines all the architectures

- The cost of implementing fluid is high, as it requires not only the cloud services but also edge computing services.
- Adding computing power to the sensors is quite costly and configuring each of them to work with other nodes and other architectural models required more expenditure than other wise needed. Hence Fluid is more costly than other computing models.

VII. VISION AND CONCLUSION

The future of the Cloud, Mist and Fog will largely be governed by machine learning and deep learning techniques, where the computations will be smarter and faster. The fluidic nature of the mist and fog with its enhanced inter-operability will provide the boost that is needed for ***Fluid computing*** to grow. The machine learning embedded in the systems will allow smart computing.

For instance, in a departmental store where each department will have some racks and they will be connected through distributed mist computing. The department will be interconnected with advanced fog architectures. The whole system will be monitored in cloud and all the transactional details will be availed via varied cloud services. This will give rise to advanced computing methods that would be heavily explored in the future yet to come. The combined efforts of mist, fog and cloud solve their individual flaws giving rise to fluid computing which is not only robust but also reliable. The system becomes more scalable, cost effective, less prone to failures and enhances the security. To conclude, this paper builds a foundation for the inter-operability of mist, fog and cloud computing through various examples and use cases scenarios.

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